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Cement and Concrete Standards Of The Future

Report from the Workshop on Cement and Concrete Standards Of The Future October 1995

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United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

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United States Department of Commerce
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CEMENT AND CONCRETE STANDARDS OF THE FUTURE: REPORT ON THE INTERNATIONAL WORKSHOP HELD ON OCTOBER 11 AND 12, 1995

ABSTRACT

The International Workshop on Cement and Concrete Standards of the Future was sponsored by the American Concrete Institute (ACI), the American Society for Testing and Materials (ASTM), the Canadian Standards Association (CSA), the Organismo Nacional de Normalizacion y Certificacion de la Construccion y Edificacion (ONNCCE), Mexico, and the National Institute of Standards and Technology (NIST). The purpose of the workshop was to provide information to guide the long-range planning of cement and concrete standards committees.

In this two-part report, Part I describes the organization of the workshop, presents summaries of invited presentations by leaders of ACI, ASTM, NIST, and keynote speaker, Bryant Mather, a past president of ACI and of ASTM, and recommendations resulting from working group discussions. Part II of the report consists of the full text of Dr. Mather's keynote presentation, "Cement and Concrete Standards of the Future."

Each working group was assigned one of three subjects:

- concrete materials standards
- concrete standards
- design and construction standards.

Among subjects addressed in the working group recommendations were:

- performance specifications
- North American and other international standards
- improved and accelerated standards development processes
- application of information technology in standards development

Keywords: building technology; cement standards; concrete standards; concrete materials standards; construction standards; design standards; information technology; performance standards; standards of the future.

ACKNOWLEDGMENTS

The Steering Committee wishes to acknowledge the support from the sponsors which gave particular significance to this international workshop:

The American Concrete Institute (ACI)
The American Society for Testing and Materials (ASTM)
The Canadian Standards Association (CSA)
The Organismo Nacional de Normalizacion y Certificacion de la Construccion y Edificacion (ONNCCE), Mexico
The National Institute of Standards and Technology (NIST)

They also wish to thank:

- All who participated in the workshop, particularly the delegations from Canada and Mexico, and the invited speakers who presented their visions of the future to help set the stage for the workshop discussions: George F. Leyh, Executive Vice-President of ACI; James A. Thomas, President of ASTM; Richard N. Wright, Director of NIST's Building and Fire Research Laboratory; and keynote speaker, Bryant Mather, Past President of both ACI and ASTM and Director of the Structures Laboratory of the U.S. Army Waterways Experiment Station.

- The Portland Cement Association, the California Portland Cement Company, and the Holnam Cement Company for their generosity in contributing financial support for meals and refreshments which sustained the workshop participants.

- The Organizing Committee and the NIST/BFRL staff who worked behind the scenes to ensure that everything went smoothly

PREFACE

The Workshop described in this report had its genesis in 1994 in the Long-Range Planning Subcommittee of ASTM Committee C01 on Cement. The subcommittee, led by Committee Vice-Chairman, Harry Harris, recognized the need for a vision of the cutting-edge cement standards of the future to help out its long-range planning tasks. It needed to try to foresee the demands that rapidly-occurring developments in areas such as concrete technology, materials science, environmental protection, computerization, and communications would have on cement and concrete standards. However, in view of the close relationship between cement and concrete standards, it was recognized that the planning would benefit from an equivalent vision of the concrete standards of the future. It was therefore decided to invite ASTM Committee C09 on Concrete and Concrete Aggregates, the American Concrete Institute (ACI), and the National Institute of Standards and Technology (NIST) to join with Committee C01 in organizing a jointly-sponsored workshop on *"Cement and Concrete Standards of the Future."* The invitations were enthusiastically accepted and a steering committee with a member from each of the four sponsoring organizations was established to begin planning the workshop. Next, in view of the growing importance of international standards, it was decided to add an additional dimension to the workshop by inviting the Canadian Standards Association (CSA) and the Organismo Nacional de Normalizacion y Certificacion de la Construccion y Edificacion (ONNCCE), Mexico, to be co-sponsors. With their acceptance, the steering committee with the assistance of a local organizing committee, completed the planning for the workshop which was held at NIST on October 11 and 12, 1995.

I wish to thank many people and organizations for their cooperation and support— the sponsors of the workshop, the members of the Steering and Organizing Committees, the speakers who set the stage for the later discussions, the Working Group Chairs, workshop participants, and the NIST staff who helped in many ways to make the Workshop a success. They are all listed in the Acknowledgments and Appendices.

I hope this workshop report will help the sponsoring organizations and others take timely action to develop the standards they will need and stimulate advances in cement and concrete technology.

Geoffrey Frohnsdorff
Workshop Chairman

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PART I

1. INTRODUCTION

The international workshop described in this report was sponsored by the American Concrete Institute (ACI), the American Society for Testing and Materials (ASTM), the Canadian Standards Association (CSA), the Organismo Nacional de Normalizacion y Certificacion de la Construccion y Edifacion (ONNCCE), Mexico, and the National Institute of Standards and Technology (NIST). Within ASTM, the sponsors were Committees C01 on Cement and C09 on Concrete and Concrete Aggregates— two committees that, perceiving a need for a vision of the future to help them in long-term planning, came together to develop the initial concepts for the workshop.

1.1 The Need for the Workshop

The stimulus for the workshop was the need to identify advances in technology and other factors that will require changes in standards for cement and concrete, or offer opportunities for improvement in cement and concrete standards or the processes by which they are developed. For example, among factors that may be expected to have substantial effects on standards are developments in computing and information technology, high-performance concrete (HPC) and material science in general, international trade agreements, and the needs for sustainable technologies.

1.2 Workshop Objectives

The objectives of the workshop were:

- To identify attributes of concrete and concrete materials that will require new or improved standards to support advances in concrete technology and help ensure attainment of the desired performance
- To discuss concepts for the future (e.g., the Year 2010) cement and concrete standards system and define the attributes of the preferred system.
- To prepare a report summarizing the attributes of the preferred system of cement and concrete standards and, if the preferred system differs from the existing system, recommend steps to be taken to make the conversion to the preferred system.

1.3 Workshop Organization

Information about the organization of the workshop is given in Appendix I: Workshop Program; Appendix II: Sponsoring Organizations and the Steering and Organizing Committees; Appendix III: List of Participants; Appendix IV: Working Groups; and Appendix V: Issues Proposed for Discussion at the Workshop. Attendance was limited to

about 60 people to ensure that all participants would have ample opportunity to participate in the working group discussions. To try to provide an equitable balance of interests, each of the sponsors nominated six participants with the Steering Committee adding other names to complete the invitation list. The actual number of persons who attended was 53. To try to ensure that all relevant topics would be considered for discussion at the Workshop, every invitee, every subcommittee chairman in ASTM Committees C01 and C09, and every committee chairman in ACI were invited in advance to offer suggestions for topics to be addressed at the workshop. A list of suggestions received is given in Appendix V; the list provides information on the status of standards for cement and concrete, and is an important part of this report.

The workshop began with a plenary session with invited presentations from leaders of three of the sponsoring organizations: ACI, ASTM, and NIST, and a keynote presentation from an outstanding contributor to standards for concrete and concrete materials, Bryant Mather. After the plenary session, six working groups of roughly equal size were given their charges; each group was assigned one of the following three topics, so there were two groups for each:

- Concrete Materials Standards–cement, aggregates, admixtures, supplementary cementing materials, reinforcing materials
- Concrete Standards–concrete production, ready-mixed concrete, proportioning, mixing, placing of concrete
- Design and Construction Standards—use of concrete, design for durability, constructability, serviceability, quality assurance, curing of concrete.

Two half-day sessions were devoted to the working group discussions. The workshop then ended in a final plenary session with presentations of reports and recommendations from the working groups, and a period of general discussion about possible follow-on actions.

1.4 Organization of the Report

Following this Introduction, Part I of the report contains Summaries of Invited Presentations and the Keynote Presentation (Chapter 2); Working Group Recommendations (Chapter 3); the Closing Session (Chapter 4), and Summary of the Workshop (Chapter 5). The keynote presentation, ***"Cement and Concrete Standards of the Future,"*** is given in full in Part II, and five appendixes containing supporting information about the workshop are given at the end; a sixth appendix presents the editors' attempt to present a vision of the cement and concrete standards of the future, if most of the workshop recommendations were acted upon.

2. SUMMARIES OF INVITED PRESENTATIONS

The invited presentations were important in providing the workshop participants with perspectives on the future of standards as seen by four leaders of organizations which will shape standards for the 21st Century. They had a significant influence on the working group discussions. Summaries of the invited presentations follow.

I. Future Standards for Concrete

George F. Leyh
Executive Vice President
American Concrete Institute

Our engineering staff and I attempted to predict how standards will evolve over the next 10 or 20 years, and found what first appeared to be a simple task to be very difficult. So the most reasonable approach is to make some assumptions about what is likely to occur in the years ahead. In the following, three general trends are presented:

1) The first trend is the increased development and use of international standards. A single international standard would be welcomed by international corporations so that their products are not arbitrarily excluded because of regional standards. However, I doubt if this trend will extend very deeply with regard to concrete construction. To begin with, concrete construction involves manufacturing in the field which can be affected by regional materials and other variables. The items of equipment used in concrete construction are not generally commodity items of world trade. Also, each nation or region will likely want to maintain control over life and safety issues involved in construction. Undoubtedly, some harmonization of standards will take place with regard to concrete construction but with regional standards still in place.

2) An increased emphasis on reusing existing buildings is apparent, and improved and new standards are needed for the repair and rehabilitation of concrete structures. Also, future buildings will be expected to better withstand catastrophic events, such as earthquakes, fires, and storms, and to be in a condition to permit occupation much sooner and at a lower cost than at present. Current standards and building codes will need to be changed to provide owners with guidance on various levels of performance existing after catastrophic events.

3) The process by which standards are developed will need to change. Volunteers often do not have enough time to devote to standards development. Also, committees are requesting more assistance from ACI in standard preparation, and industry and academia are growing impatient with the current process of transferring research into standards. In

response, the creation of an electronic network facilitating communications between committee members, and between them and ACI staff is becoming a necessity. In addition to changes in the standards development process, new standards are needed because of advances in concrete technology such as high-performance concretes with increased strengths and longer service lives. Also, standards of the future must allow and encourage evolving technologies such as knowledge-based systems.

II. The Future of Standards

James A. Thomas
President
American Society for Testing and Materials

During the past 20 years, dramatic changes have taken place in U.S. voluntary standards organizations. In the 1970s, antitrust was a greater concern than competition, and attempts were made to regulate the voluntary standards system. People were willing to accept slowness, checks and balances, wide open discussions and endless debates in the process of developing standards. Today, competitiveness is more of a concern than antitrust, and standards are coming to be regarded as documents of trade. People are now looking for results—they want standards that drive their product into the marketplace, and that will enable them to accomplish their marketplace objectives. The international standardization trend is going to continue and intensify. The U.S. Government, through the U.S. Trade Representative's Office, is reducing technical barriers to trade by agreeing to the use of international standards. Therefore, for the U.S. construction industry to be competitive in foreign trade, it must develop standards that can be used as international standards, as well as developing relationships with international standards organizations.

The standards developing process is undergoing a revolution with an increased utilization of electronic technology driving the process. ***ASTM has an E-mail address and has put a home page on the World Wide Web,*** and it is developing procedures for ASTM task groups to develop standards using the Internet. Some ASTM committees are not meeting as frequently as they did in the past because they are using phone conferences, fax, and other electronic technologies to develop standards. This remote standards development process will grow, resulting in significant changes in standards organizations.

III. Standards Media and Methods[1]

Richard N. Wright
Director
Building and Fire Research Laboratory
National Institute of Standards and Technology

The trend to a global marketplace and advances in information technologies are leading to great changes in standards. These include growing reliance on international rather than national standards, new standards development techniques and procedures, and new media and environments in which standards are expressed and used. Both general purpose and project-specific information are being stored and accessed from distributed, electronic, object-oriented data bases. Standards will themselves become executable objects available from general purpose systems. Use of such standards will be convenient and efficient: input data will be accessed automatically from pertinent fields of the general purpose and project-specific data bases; results of evaluations will be recorded automatically in the project-specific data base and used in subsequent decisions affecting design, construction or operation of constructed facilities.

At present, standards expressed by text are incorporated into computer-aided design or design review systems by programmers who are unlikely to understand the standards or to program them correctly. The major uses of standards are coming to be associated with such computer-aided systems and the major revenues from uses of standards will accrue to the system developers and users. Standards developing organizations should respond to this marketplace, which is replacing the marketplace for standards expressed by text, by themselves producing standards in the form of executable objects (or, equivalently, as knowledge-based expert systems).

Computer aids, equivalent to *"shells"* for development of expert systems, can assist in the formulation and expression of standards that are complete in coverage of the intended scope, consistent and unambiguous in their logic, and correct in the evaluation of the pertinent product or service.

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[1]The full text is published in the Proceedings of the CIB-ASTM-RILEM 3rd International Symposium on "*Applications of the Performance Concept in Building.*" (Tel Aviv, Israel December 1996).

IV. Keynote Address: Cement and Concrete Standards of the Future[2]

Bryant Mather
Director
Structures Laboratory
U.S. Army Engineer Waterways Experiment Station

In order to properly plan for cement and concrete standards for the year 2010, we need to decide what we want standards for and which standards should be of what sorts: national versus local, consensus versus proprietary, voluntary versus mandatory, etc. We need then to consider the economic framework within which cement and concrete will be produced, marketed, and used. We also need to review the issue of performance standards versus prescriptive or design standards, and standards with different acceptable limits based on a variety of considerations.

Four topics for consideration during the workshop are:

1. Performance standards versus design or prescriptive standards.
2. Graduated acceptance limits based on degree of noncompliance.
3. Graduated acceptance limits based on environmental severity.
4. Graduated acceptance limits based on desired service life.

Every requirement of a standard should be traceable to some aspect of performance of the material, product, system, or service covered by the standard. Also, the specifying body should be prepared–based on the standardization development history of the document–to defend the selection of any of the requirements, both as to their nature and quantity, as being the best approach under the current state-of-the-art for ensuring, with acceptable risk of error, the level of performance needed. In addition, performance tests are necessary so that cements and concretes with novel compositions can compete and innovative materials or systems can be evaluated. However, in some cases, prescriptive limits are justified, e.g., limits on alkali contents of cements to prevent alkali-aggregate expansive reactions.

Graduated acceptance limits based on degree of noncompliance with target requirements involve reduced payments when a material fails to meet specification requirements but still should perform adequately. Graduated acceptance limits considering environmental severity already exist, e.g., restrictions on tricalcium aluminate content of cement are based on the sulfate concentration in the environment. No standard appears to exist for graduated acceptance limits based on desired service life.

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[2]The full text of Dr. Mather's paper is given in Part II of this report.

It is predicted that in 2010 concrete will still be a composite material consisting of cementitious materials, aggregates, admixtures, water, and often mixed-in reinforcement of nonstructural sorts. All of these ingredients will need purchase specifications and methods of testing to determine compliance, not only with the provisions of the purchase specification, but also with the requirements for concrete as used in making structural or other elements, either in the factory or at the job site.

3. WORKING GROUP RECOMMENDATIONS

In this chapter, the results of the working group discussions are, for the most part, presented in the form of specific recommendations, with commentary where needed. It is believed that this format will make the report most useful to the interested standards committees which will undoubtedly need to carry out their own discussions about what action, if any, to take on the recommendations.

3.1 Concrete Materials Standards

Working Group 1	**Working Group 2**
Chair: David Fowler	Chair: Robert Helinski

Working Groups 1 and 2 addressed standards for concrete materials. For the purpose of the workshop, concrete materials denoted the constituents of concrete, including primary and supplementary cementing materials, chemical and mineral admixtures, aggregates, reinforcing materials, and mixing water. In the U.S., standards for these materials are the responsibility of ASTM Committees C01 on Cement and C09 on Concrete and Concrete Aggregates.

The recommendations from the two working groups were similar, largely addressing the need for performance standards and the culture of standards development, and the maintenance and use of standards.

3.1.1 Future Standards

- RECOMMENDATION: Standards for concrete materials should be performance-based, with prescriptive alternatives. ***Commentary:*** *Future standards will need to cover the important performance attributes required to assure adequate field performance, e.g., meeting a strength requirement does not necessarily assure that a concrete will be durable in a specific environment. New performance tests and material characterization methods will be needed for implementing performance standards. Materials science research will be needed to establish performance criteria, including modeling of material*

performance, development of databases on material properties, and the development of knowledge-based systems. Standards for service life design, consisting of a methodology or standard practice, may be needed.

3.1.2 Standards for Systems of Materials

- *RECOMMENDATION:* Standards should address the compatibility of concrete materials, e.g., the influence of mineral admixtures (supplementary cementing materials) on the performance of chemical admixtures.

- *RECOMMENDATION:* A standard methodology should be developed to enable the prediction of the performance and service life of concrete based on the properties of its constituents.

3.1.3 Developers of Standards

- *RECOMMENDATION:* ASTM and ACI should maintain their respective roles, with ASTM being responsible for standard test methods and specifications for materials and ACI being responsible for construction practices. ***Commentary:*** *A joint ACI/ASTM committee was suggested as a method for optimizing the interactions between the two organizations. In regard to the relationship between ASTM Committees C01 and C09, the majority was in favor of retaining both ASTM C01 and C09, but with improved communications and planning between them.*

3.1.4 Development of Standards

Several recommendations were given for improving the standards development process:

- *RECOMMENDATION:* Applicable research results should be identified and evaluated to determine suitability for inclusion in standards.

- *RECOMMENDATION:* Research that can form the basis for improving existing standards or establishing new standards should be encouraged. Standards committees should do more to provide researchers with statements of research needs.

- *RECOMMENDATION:* A mechanism should be established for providing to standards committees that desire it, the assistance of knowledgeable standards preparation facilitators.

- *RECOMMENDATION:* Communication within committees should be optimized, possibly by electronic communication using e-mail and electronic conferencing.

- *RECOMMENDATION:* Shells, similar to those for developing expert systems, should be used to facilitate the computer-assisted preparation of standards.

- *RECOMMENDATION:* A mechanism should be established to provide enhanced funding for research needed for standards development and for standards development activities.

3.1.5 Standards Style and Terminology

- *RECOMMENDATION:* Wherever applicable, mandatory language should be used in ASTM and ACI standards and guides.

- *RECOMMENDATION:* In order to preclude misunderstanding of provisions of standards, the provisions should be object/property driven.

- *RECOMMENDATION*: Standards should be *"user-friendly"*, i.e., standards should use language which, as much as possible, can be easily understood by the whole range of users.

- *RECOMMENDATION*: The use of SI units in standards for concrete materials should be strongly encouraged.

3.1.6 Acceptance of Standards

Some recommendations which may affect the acceptance of standards are given in Section 3.1.5, Standards Style and Terminology. Other recommendations include:

- *RECOMMENDATION*: Guides, possibly in the form of expert systems, should be developed for selecting and using standards. ***Commentary****: The selection process must also deal with layers of referenced standards which may be several layers deep.*

- *RECOMMENDATION:* Increased attention should be given to education of potential users about the standardization process and the development and use of standards.

3.1.7 International Standards

- *RECOMMENDATION:* ASTM and ACI should jointly be involved in international standards development through ISO. ***Commentary:*** *Though this recommendation was supported by a majority of participants, some felt that international standards were not of paramount importance to the U.S. construction industry.*

- *RECOMMENDATION:* Standards that support the North American Free Trade Agreement (NAFTA) should be developed and promulgated.

3.2 Concrete Standards

Working Group 3
Chair: Douglas Hooton

Working Group 4
Chair: Oscar Tavares

Working Groups 3 and 4 addressed standards of the future for concrete including concrete production, ready-mixed concrete, and preparation, mixing and placing of concrete. Also included were standards for quality control testing and inspection, and test methods for predicting the performance of concrete. ASTM Committee C09 on Concrete and Concrete Aggregates deals with test methods and specifications for concrete materials, and ACI Committees deal with aspects of concrete construction.

3.2.1 Existing Standards

- *RECOMMENDATION*: Existing standards should be critically reviewed to determine if modifications are necessary or if certain standards should be replaced. ***Commentary:*** *The standards should be evaluated considering: (1) the relation of test results to field performance; (2) the possibility of modification to give more reliable predictions of performance; (3) the precision of test results; (4) consistency with the current state-of-the-art technology. Standard test methods specifically mentioned were tests for sulfate resistance, freeze-thaw resistance, and alkali-aggregate reactivity.*

3.2.2 Future Standards

- *RECOMMENDATION:* Performance-based standards should be developed for concrete used in new construction, repair, and rehabilitation. **Commentary**: *Performance standards will require the development of field and laboratory performance tests which realistically simulate field exposure conditions and degradation processes. A materials science approach, including simulation modeling, should be taken in developing performance criteria and in developing test methods for measuring and predicting properties of concrete.*

- *RECOMMENDATION*: Standards should be in electronic form incorporating multi-media representations of knowledge where appropriate.

3.2.3 Needed Standards

Two areas where there are no existing standards and where standards are needed are

selection of repair materials and systems, and service life design and service life prediction. A major cause of problems occurring with the performance of repair materials is lack of compatibility of the repair materials with the concrete to be repaired.

- *RECOMMENDATION*: Develop performance-based specifications for selecting compatible repair materials, considering the service environment, the properties of the existing concrete, and the specific application, e.g., structural repair or protective surface repair.

- *RECOMMENDATION:* Develop performance criteria to form a sound basis for the selection of repair materials including criteria for drying shrinkage, early-age tensile strength, tensile creep, coefficient of thermal expansion, and modulus of elasticity.

- *RECOMMENDATION*: A standard methodology or practice for service life design should be developed. ***Commentary****: A methodology for service life design of high-performance concrete (HPC) is needed as extended life is likely to be an attribute that could make it cost-effective. A classification should be developed for concrete based upon predicted service lives, possibly in terms of time intervals.*

- *RECOMMENDATION:* A classification of service life requirements for concrete similar to that used in many countries for strength requirements of concrete, should be developed.

- *RECOMMENDATION:* To aid prediction of the service life of concrete, standard test methods should be developed to measure rates of transport of fluids in concrete, including the diffusion of gases and liquids, and permeation and capillary flow (sorption) of liquids.

- *RECOMMENDATION:* Standard test methods should be developed for determining toughness, thermal compatibility of concrete constituents, and water-to-cement ratios; standards are also needed for inspection using radar and stress waves.

3.2.4 Quality Control and Quality Audits

- *RECOMMENDATION:* Improved standard methods and practices for quality control (QC) of concrete should be developed to ensure that the hardened concrete achieves its designed properties.

- *RECOMMENDATION:* Standards should be established for certification of personnel of test laboratories, ready-mixed concrete and prefabrication plants, and contractors involved in QC.

- *RECOMMENDATION*: To improve product quality, an information management system coupled with real-time monitoring and inspection of concrete processing should be developed.

- *RECOMMENDATION:* Improved standard methods for performing quality audits of concrete prior to commissioning of a structure should be developed to insure that the structure will meet its design life. Non-destructive acceptance tests should form the basis of the quality audits.

3.2.5 Harmonization of Standards

- *RECOMMENDATION:* An integrated global system for representing and exchanging test results should be developed, which would, at least, provide a permanent mechanism for comparing results obtained using test methods from different standard systems, e.g., ASTM and European standards. ***Commentary:*** *Both working groups were in favor of standards that supported NAFTA and were in accord with ISO activities.*

- *RECOMMENDATION*: The use of SI units should be encouraged.

- *RECOMMENDATION:* Increased interaction between ACI and ASTM was recommended, with each retaining its role in standards development, e.g., ASTM being responsible for test methods and specifications for concrete and concrete materials, and ACI largely responsible for construction practices and performance attributes.

- *RECOMMENDATION:* ASTM Committees C01 and C09 and ACI should be active in relevant ISO Committees.

- *RECOMMENDATION* (from Working Group 4 only): ASTM Committees C01 and C09 should be combined. ***Commentary:*** *Work Group 4, without dissension, thought that unification of C01 and C09 would streamline the development of standards for concrete and facilitate the development of standards for the prediction of the performance of concrete based on its constituents ' properties and their compatibilities.*

3.2.6 Environment for Standards Development

The results of discussions and recommendations relative to development of standards were essentially the same as those recorded for the Concrete Material working groups (see Section 3.1). Major issues discussed were:

- funding for research needed to support standards development;
- difficulties in sustaining volunteer participation in standards committees;

- need for paid consultants to assist committees in standards preparation;
- development of a "*shell*" to use in computer-assisted development of new standards;
- consolidation of committees to reduce duplication of standards;
- the need to educate new engineers about the standardization process and the development and use of standards.

3.3 Design and Construction Standards

Working Group 5	**Working Group 6**
Chair: Gene Corley	Chair: Richard White

Working Groups 5 and 6 on Design and Construction Standards addressed topics relating to standards of the future such as the use of concrete, design for durability, constructability, serviceability, quality assurance, and the curing of concrete.

In the U.S., ACI Committee 318 on Standard Building Code has the responsibility "to prepare and update on a continual basis building code requirements for plain and reinforced concrete."

3.3.1 Performance-Based Standards

- *RECOMMENDATION:* Standards and codes for concrete should have provisions for the durability of concrete as is the case for strength. ***Commentary:*** *Concrete durability and how it affects the long-term serviceability of a structure is not adequately covered in current codes and standards.*

- *RECOMMENDATION*: Standards and codes should be changed in response to an increasing demand that they allow owners to select the levels of performance for a constructed facility, provided life safety is not compromised.

- *RECOMMENDATION:* Develop and document a rational basis for establishing performance requirements for durability/service life, and serviceability. ***Commentary:*** *Working Group 5 felt that prescriptive criteria will continue to play an important role far into the future, filling voids where no performance criteria exist. For example, in selecting the service life of a facility, the owner might be allowed to choose from alternatives such as: (1) 100-year service life without the need for rehabilitation; (2) 100-year service life with rehabilitation every 25 years; or (3) temporary structure to be demolished in less than 25 years.*

- *RECOMMENDATION*: Performance test methods, performance standards, and performance prediction methodologies should be developed for assessing and quantifying the durability/service lives of alternative material and system designs. ***Commentary:*** *The*

ability to demonstrate equivalence in durability is critical for new technologies, e.g., alternative materials, since it is often the major barrier to gaining code approval.

3.3.2 New Concrete Design and Construction Standards

Recent technological developments are resulting in demands for several new concrete design and construction standards.

- *RECOMMENDATION:* For fiber-reinforced concrete, performance tests and criteria, linked to material toughness and structural ductility properties, should be developed for measuring energy dissipation at the level of structural elements and joints.

- *RECOMMENDATION:* For fiber-reinforced plastic (FRP) reinforcement, performance criteria and design/construction standards should be developed for its use in concrete structures. ***Commentary:*** *The standards are needed because of differences in performance with regard to bond and failure mechanisms compared to ordinary (steel) reinforcement.*

- *RECOMMENDATION*: For hybrid concrete construction, standards should be developed to deal with both conventional and innovative hybrid construction consisting of concrete with one or more of steel, aluminum, and fiber-reinforced plastic composites.

- *RECOMMENDATION:* For repair, retrofit, and rehabilitation, standards should be developed that address the performance and selection of repair materials and systems, condition assessment, and performance levels for upgraded structures. ***Commentary:*** *The growing market for repair, retrofit, and rehabilitation of existing facilities is generating the need for new standards applicable to these technologies.*

- *RECOMMENDATION*: ACI, ASTM, ASCE, and other interested organizations should develop a national plan for addressing the unique issues related to repair, retrofit, and rehabilitation of existing concrete structures.

- *RECOMMENDATION:* Active and passive standards for vibration control systems should be developed for slender structural components and systems using high-strength concrete. ***Commentary:*** *Active and passive damping systems are being developed to control vibration in concrete structures and, as yet, there are no standard test methods for evaluating them.*

3.3.3 Prediction of Life-Cycle Costs

The cost to operate and maintain a structure is often as important as its initial cost. This can be estimated by life-cycle cost analysis which considers long-term durability and serviceability in projecting future costs of operating and maintaining a structure.

- *RECOMMENDATION:* The life-cycle cost analysis standards of ASTM Committee E06 should be reviewed to determine their applicability to concrete structures, and to develop any additional tools which are needed; the standards should consider predicted service lives in their analysis.

3.3.4 Harmonization of Standards

- *RECOMMENDATION:* Standards which support NAFTA should be developed by harmonizing Canadian, Mexican and U.S. standards.

- *RECOMMENDATION:* The complete conversion of ACI and ASTM Standards to SI units should be carried out rapidly.

- *RECOMMENDATION* (Working Group 5 only): North American standards should satisfy the general provisions of ISO standards.

- *RECOMMENDATION* (Working Group 5 only): A joint industry-government program should be established to provide support for monitoring ISO and European standards activities, analyzing differences between European and North American standards, and supporting North American leadership in this effort. ***Commentary:*** *To ensure that international competitiveness of the North American construction industry remains strong, it is vital that North American standards organizations work with European pre-code committees.*

3.3.5 Environment of Standards Development

The results of discussions and recommendations relative to development and maintenance of design and construction standards echoed those of the Concrete Material Standards and the Concrete Standards working groups. Working Group 6 concluded that *"The current level of available resources (money, people, and organizational commitment) is not adequate to sustain U.S. standards and codes development into the 21st century."*

- *RECOMMENDATION* (Working Group 6 only): The following actions should be pursued: (1) accelerate the standards and codes development process; (2) promote combined funding from government and industry to develop the needed technology base

- for standards and support participation by qualified individuals; (3) improve the skills of the volunteers (especially chairpersons) who participate in committees; (4) streamline the consensus process, possibly allowing multiple levels of simultaneous approval; (5) educate college students and practicing engineers about standards and codes development processes; and (6) bring other interested groups, such as the insurance industry, into the standardization process.

- *RECOMMENDATION*: The process of standards development and maintenance should take advantage of new technologies including electronic communication between committee members, use of *"shells"* and computerized integrated knowledge systems for preparation of standards, and use of CD-ROMs and the Internet rather than paper copies to disseminate standards and codes.

3.3.6 Innovation in Concrete Design and Construction

- *RECOMMENDATION:* No specific recommendation. ***Commentary****: The following comments (from Working Group 5) appear to define the status of innovation in concrete design and construction. "While there are demands for new standards for new applications, existing standards and codes have generally worked well and do not seem to stifle innovation. All model codes allow innovation provided that the alternative technology can be demonstrated to satisfy equivalence with code requirements. The greatest barriers to innovation appear to be (1) owners who are not willing to pay the higher cost for better performance or life-cycle cost, and/or to bear the cost of failure which may have a higher probability because of innovation; and (2) lack of education or knowledge, especially among recent graduates, about existing standards and code provisions that support innovation."*

4. CLOSING SESSION

At the final plenary session of the workshop, working group chairs reported on their groups' discussions and recommendations. While it was clear from the wording that some recommendations were stronger than others, no attempt was made at prioritization.

The group reports were followed by a period of general discussion. During the discussion, unanimous agreements were reached that:

- North American cement and concrete standards organizations should work more closely together to advance and harmonize their standards;
- US cement and concrete standards should be metric and use SI units;
- Follow-on activities should be planned to refine and further develop the recommendations and foster action upon them.

5. SUMMARY OF THE WORKSHOP

In summarizing, it must be emphasized that this workshop report is but a single contribution to the ongoing dialog needed to ensure continuing improvement of cement and concrete standards.

At the start of the workshop, the four invited speakers provided a broad range of ideas to stimulate discussion in the six working groups. Among points they made were:

- Standards will be needed for the foreseeable future.
- Processes for developing and maintaining standards which used to be adequate require significant change.
- Standards-developing processes must be accelerated because of the growing impact of competition among standards on both national and international commerce.
- The preparation and dissemination of standards and codes are evolving rapidly from the age of printed media to the electronic age.
- To retain their leadership position, leading standards-developing organizations must lead the revolution in electronic standards creation and maintenance.

In working group discussions which followed, one group expressed a serious concern that, in the U.S., "the current level of available resources (money, people, and organizational commitment) is not adequate to sustain ..... standards and codes development into the 21st century." Specific recommendations concerning improvement of the environment for standards development fell into several main areas:

- The need for research to provide a sound technical basis for standards;
- The funding of the research needed to support standards development;
- The need to reverse the waning commitment of standards users to support the development and maintenance of standards;
- The use of electronic communications and computerized systems to facilitate standards development and maintenance.

Several recommendations concerned international standards. A need for harmonization of cement and concrete standards on a North American or larger international level was expressed by each of the groups, with special importance being given to it by a group concerned with design and construction standards. One group recommended establishment of a joint industry-government program to support monitoring of ISO and European standards activities, analyzing differences between European and North American standards, and supporting North American leadership in international standardization, or harmonization of standards. Also, to insure that international competitiveness of the North American

construction industry remains strong, the group recommended that North American standards organizations should work with European pre-standardization committees. Strong support was given by all the groups for standards that would support NAFTA.

The relationship between ASTM Committees C01 on Cement and C09 on Concrete and Concrete Aggregates was discussed by four of the groups. Only one group supported the idea of merging the committees; it felt a merger would facilitate the development of standards relating to the compatibility of the constituents of concrete; at the least, interaction between the committees should be strengthened. Regarding ASTM and ACI, it was generally felt that they should continue their present roles, with ASTM being responsible for standards for test methods and specifications and ACI for construction practices; there was some sentiment for establishment of a joint committee between the two organizations to improve their interactions.

The groups brought forth many recommendations for new standards necessitated by advances in concrete technology and changes in concrete materials. Among them were recommendations for standards in the following areas:

- Material-science-based performance standards;
- Standards addressing the compatibility of concrete materials in relation to concrete performance;
- Standard test methods for use in predicting the performance of high-performance concrete;
- Standard methodologies for predicting service life of concrete;
- Standards addressing the performance of materials and systems for repair of concrete;
- Standards for composite reinforcement and hybrid constructions of concrete with other materials.

In addition, it was recommended that ASTM Committees C01 and C09 should critically review their existing standards to determine if changes were necessary or if certain standards should be replaced.

At the closing session of the workshop, it was agreed to recommend that North American cement and concrete standards organizations should work more closely together to advance and harmonize their standards, and that US cement and concrete standards should be metricated and use SI units. Finally, it was recommended that activities following on from the workshop should be planned to refine and further develop the workshop recommendations and foster action upon them.

PART II

KEYNOTE PRESENTATION

"CEMENT AND CONCRETE STANDARDS OF THE FUTURE"

by

Bryant Mather

Director, Structures Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180-6199

ABSTRACT

In order to properly plan for cement and concrete standards for the year 2010, we need to decide what we want standards for and which standards should be of which sorts: national versus international, national versus local, consensus versus proprietary, voluntary versus involuntary, etc. We then need to consider the economic framework within which cement and concrete will be produced, marketed, and used. We also need to review the issue of performance standards versus prescriptive or design standards and standards with different acceptance limits based on a variety of considerations. Finally I pass on a comment about ethics.

INTRODUCTION

When I was asked by Geoffrey Frohnsdorff to be the keynote speaker for this workshop, the thought that came to mind was "Why me?" What could I present that would be useful to the participants as they begin their deliberations? I already had been invited to attend and was aware of the purposes of the workshop: (1) To identify attributes of concrete and concrete materials that should be dealt with using new or improved standards to support advances in technology so concrete will behave as we want it to; (2) to guess what it is we would like to have as a standards system for concrete and concrete materials in 2010; and (3) to make plans for getting there. As you see, I paraphrase.

You note that I mentioned that before I was asked to prepare these remarks, I had been invited to attend the workshop. As part of that exercise, I was asked to suggest topics that might be addressed. Four spaces were provided. My four suggestions were:

1) Performance Standards Versus Design or Prescriptive Standards.
2) Graduated Acceptance Limits Based on Degrees of Noncompliance.
3) Graduated Acceptance Limits Based on Environmental Severity.
4) Graduated Acceptance Limits Based on Desired Service Life.

STANDARDS

Having reviewed some generalities and perhaps sown a few seeds for discussions that will arise, let me now discuss what I think is meant by standards. A good many years ago, when I was on the ASTM Board, it decided to have a project to describe what it thought the Voluntary Standards System of the United States ought to be. I ended up on the committee to draft the document. We started, naturally, with the issue of what sorts of things should be produced by the system we were to design. We rapidly became aware there were lots of standards that should not be national and lots that should not be voluntary. There may be a lot of standards relating to cement and concrete that probably should not be national or consensus or voluntary. For example, should ASTM have a standard putting limits on aspects of the fuel used by a cement producer in producing clinker? Should ASTM have specifications for oil-well cement? Should there be specific licensing requirements (standards) for forensic experts in the elucidation of the behavior of concrete? The report "The Voluntary Standards System of the United States of America" was published by ASTM in 1975 as a 31-page pamphlet. Chapter VI is called "The Ideal System." Since this workshop is to prepare a report on the standards system we would like to have in 2010, I attached a copy of this chapter as an appendix to these remarks.

ASTM recognizes a variety of subjects for standardization and ACI generally concurs. It is agreed that there should be building codes, test methods, product specifications, terminology, practices, guides, bases of accreditation and licensing, and others. ASTM and ACI have a long-standing agreement to avoid conflict and duplications. Under this agreement, ASTM has agreed not to prepare building codes or design standards and standards for many sorts of activities in the field on the jobsite while ACI will not prepare test methods and specifications for over-the-counter products. Both organizations are still somewhat ambiguous - in my opinion - as their role in standards for licensing and accreditation. The September, 1993, ACI committee list includes a "Certification Program Committee" which in 1991 took over the work of a previous Educational Activities Committee on Certification. There are separate certification committees on the following subjects: (1) Formwork Designer/Detailer, (2) Shotcrete Nozzle man, (3) Field Technicians, (4) Laboratory Technicians, (5) Construction Inspector, and (6) Craftsmen. ASTM Committee E32 on "Criteria for Evaluating Agencies Concerned with System Analysis, Testing, and/or Compliance Assurance of Manufactured Buildings," established in 1972, was merged in 1981 with E06 on "Performance of Buildings." Committee E36 on "Laboratory Accreditation" was established in 1973. It is responsible for "generic" standards for criteria. It has a subcommittee, E36.70 for "Accreditation Criteria for Agencies Involved in Building Construction," which may or may not (I just do not know) have a liaison with C09.98 on "Evaluation of Laboratories" and C01.95 on —"Coordination." C01.95 has jurisdiction over C1222, "Standard Practice for Evaluation of Laboratories Testing Hydraulic Cement." C09.98 has jurisdiction over C1077, "Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria

for Laboratory Accreditation." Generally it is still agreed, I believe, that somewhere there is a line across which the voluntary consensus standards activities do not cross because crossing it gets one involved with the police power of the state as it is used to enforce laws and regulations based on laws. I suggest that the people here will need to decide what standards are needed before one can deal reasonably with who shall produce them and then decide what they should say and how they should say it.

CONCRETE AND CONCRETE MATERIALS

Having commented on generalities and reviewed some aspects of standards, I now turn to the subject matter of the workshop: cement and concrete.

I do not have any clear picture about how one will specify concrete work in 2010. There is a possibility that one will order a road or a bridge or a building or a dam, say where you want it put, what you want it to do, and receive proposals from folks who are prepared to put what you want in place and have it ready to be used on a certain day for a stated price. If this maturation of the design-build concept should come to pass, it does not really necessarily change anything about standards for concrete and concrete materials; all it will do is to have the builder select what will do the job rather than have the owner hire someone other than the builder to do this.

In 2010, I predict that concrete will still be a composite material consisting of cementitious materials, aggregates, admixtures, water, and often mixed-in reinforcing of nonstructural sorts. All of these ingredients will need purchase specifications and methods of testing to determine compliance not only with the provisions of the purchase specification but also with the requirements for concrete as used in making structural or other elements, either in the factory or at the jobsite.

THE YEAR 2010

This is the first meeting I have been involved with dealing with the year 2010, but I have been more or less involved with several dealings with the year 2000. I was a member of the committee chaired by Clyde Kesler appointed by the ACI Board to describe - so one could plan for it - "Concrete Year 2000" (Kesler [Chairman], 1971). In 1980, at Mohan Malhotra's request, Clyde updated his report as "Concrete for the Year 2000"(Kesler, 1980). In 1992, Mohan got Adam Neville to try his hand at this, and "Concrete in the Year 2000" appeared (Neville, 1992). Then in 1994, Kumar Mehta got me to try, and "Concrete Year 2000, Re-visited" appeared (Mather, 1994). Mohan asked me to rework it for the Neville Symposium and "Concrete - Year 2000, Revisited in 1995" appeared (Mather, 1995). In Mather 1995, I cited some of the 1993 predictions of the Civil Engineering Research Foundation, which include some related to standards, including: (1) concrete with "enhanced" ease of placement

and compaction without segregation; (2) early age strength; (3) toughness; (4) volume stability; (5) life in severe environments; and (6) a streamlined standards development process will facilitate technical innovation, and concrete will have to meet global standards. There is at present no recognized standard test for toughness of concrete. I suspect there needs to be one.

I have no idea what the CERF people meant by "a streamlined standards development process will facilitate technical innovation and concrete will have to meet global standards." My view is that if concrete meets relevant U.S., i.e., ASTM/ACI, standards, it does not need to worry about the rest of the world, if that is what was meant by "global." If by "streamlined standards development" they meant a procedure intended to get out a new standard quicker that is now customarily done through ASTM and ACI, I doubt that we need help from outside ASTM and ACI to do this. If it is believed that present standards or standards-development processes stifle innovation, it may be that in some rare cases, this has been true. The move toward performance specifications was such a hot topic back in 1975 that I was interviewed about it when I was President of ASTM. It was believed by some, mostly The Federal Trade Commission, that composition or design specifications could restrict competition and stifle innovation. I can not think of a case of this in the concrete field, but progress is being made in the movement toward performance specifications.

The three speakers who have preceded me in this Plenary Session have covered the essential features of the workshop. I looked up "Plenary" to see if there was anything in the definition of "plenary" that implied what was intended or required to be done in such a session. There is not. A "plenary" session is merely a session to which all the delegates are permitted to come; it implies nothing about what is intended to be accomplished.

Therefore, I will only take a few minutes to outline the ideas I had when I made the suggestions that I mentioned earlier for this workshop.

1) **Performance Standards Versus Design or Prescriptive Standards.** I think every requirement of a standard should be traceable to some aspect of performance of the material, product, system, or service covered by the standard. Also, the specifying body should be prepared - based on the standardization development history of the document - to defend the selection of any of the requirements, both as to their nature and quantity - as being the best approach under the then current state-of-the-art for ensuring, with acceptable risk of error, the sort of performance needed. This does not mean that there must be no prescriptive limits. I believe it can be shown and probably will continue to be shown that it is simpler, quicker, more economical to ensure satisfactory cement performance relative to alkali-aggregate reaction by limiting the alkali content of cement than running a simulated service performance test. Likewise, satisfactory performance relative to sulfate attack can, I believe, be ensured quicker and more simply by a limit on C_3A calculated from chemical analysis than running a performance test. But we need to have, and we do have, performance tests so that cements

and concretes with novel compositions can compete and innovative materials or systems can be evaluated.

2) **Graduated Acceptance Limits.** I believe we should have a series of limits for most acceptance purposes. We now do in many cases. We need more. I suggested three areas in which they might be used:

a) Based on degree of noncompliance with target requirements: There is a draft Specification of Concrete Pavement for Airfields and Other Heavy-Duty Pavements (CDGS 02513, April 1994) prepared for the Corps of Engineers by Oswin Keifer in Portland, OR, that has a provision reading "When a lot of material fails to meet the specification requirements, that lot will be accepted at a reduced price or shall be removed and replaced." These procedures deal with requirements for aggregate grading; concrete air content, strength, and slump; and pavement smoothness and thickness. Today, too often after the fact, it is clear that the work has not been done so as to comply with the requirements of the contract, but it is equally clear that the defects do not justify removal and replacement, but no basis exists for acceptance at a reduced price. Such provisions would be desirable in many cases.

b) Based on environmental severity: We have a lot of these. One selects the level of restriction on C_3A in cement based on concentration of SO_4 in the environment (ACI 201.2R, Table 2.2.3). One selects the amount of deleterious substances allowed in aggregate based on regional severity of weathering and the exposure of the construction (ASTM C33, Table 3). One selects air content of concrete based on severity of exposure and nominal maximum size of aggregate (ACI 318, Table 4.2.1).

c) Based on desired service life: I do not personally know of a standard for concrete where one is given specific guidance for more restrictive limits because the desired service life is longer, but, of course, designers and specifiers have been doing this at least since the time of Vitruvius. The folks dealing with the use of concrete for encapsulating or otherwise isolating nuclear waste keep asking how they can be sure the concrete will maintain its integrity for some hundreds or thousands of years. My answer to this question has been, for the last 30 years or so, that concrete is a synthetic sedimentary rock. Sedimentary rocks exist that are in good physical condition after several hundred million years of service. If you can select an environment like that in which these old rocks have spent their service life, we can build a concrete of similar relevant properties that will maintain its integrity just as long. Alternatively, I say "Tell me the rate at which the concrete will be attacked, and make the structure thicker by an amount equal to the micrometres per year deterioration rate times the desired service life, and at the end of the service, it will be just as protective of its interior as it needs to be." At the semiannual meeting of the National Science Foundation (NFS) Center for Advanced Cement-Based Materials held in September 1995 in Evanston which I attended for Dr. Tony Liu, several references were made to research that could yield data that might provide an improved basis for service-life prediction of concrete. I failed to see how any of

the data that were presented by any of the researchers who had cited this goal might actually improve service-life predictions, but they did not claim that this was yet practical. I guess it fell under what might happen but has not happened yet.

One last comment: In the magazine of the cement industry of the Netherlands for April 1995, I was interested to see the following: "Does the future of concrete have anything to do with ethics? Any human activity has an ethical dimension. This is true of science and technology, as therefore for civil engineering too. The future of concrete will not be affected so much by ethical considerations, but mainly by technical, economic, social and ecological developments. Nevertheless ethical guidelines can contribute to the attitudes adopted. If the construction industry acts responsibly, with a keen realization of the contribution it can make, concrete as a construction material will have an important role in the future. At the beginning of any technical venture all those involved should ask themselves in principle: 'Will this do more harm than good?' In the many cases where those involved do not consider it incumbent upon them to stand on the sidelines, they should follow some ethical guidelines, which apply to all areas of science and technology."*

* Cement, Vol 47, No. 4, April 1995, Netherlands Cement Industrie.

APPENDIX

THE IDEAL SYSTEM*

The voluntary standards system of The United States is, in its present form, not the ideal system. Since we, in ASTM, intend to contribute to improvement of the system, we here attempt to outline the "ideal" system.

The total standards system includes both the voluntary standards system and the nonvoluntary, regulatory-standards system. The degree to which the voluntary standards system has matured and become effective in a segment of society may be expected to have an effect on the degree to which the nonvoluntary, regulatory standards system is developed in that the voluntary standards system provides criteria and may recommend regulatory limits, but does not directly participate in setting legally binding regulatory limits on permissible behavior of individuals and organizations. It is also assumed that the need for standard methods, standard definitions, standard classifications, standard procedures, standard criteria, and standard practices, covering aspects of properties, composition, performance and behavior of materials, products, systems, and services will increase with time.

The principles upon which the ideal voluntary standards system is based must be selected to maximize the degree to which the system operates to achieve:

a) Timely response to needs for standards.
b) Adequate response to needs for standards.
c) Selection of activities to be undertaken for the development and application of standards.
d) Inclusiveness or participation of all parties at interest in the standards-making process.
e) Fairness in resolution of the differences among parties at interest.
f) Creation of regulations governing procedures for standards-making with built in flexibility to meet changing conditions.
g) Coordination among groups engaged in standardization, nationally and internationally.

The ideal voluntary standards system includes a mechanism that:

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*From "The Voluntary Standards System of the United States of America," ASTM. 1975 Philadelphia, PA, 31 pp.

1. Continually surveys the need for standards by all elements in the society and provides access to the system by all parties.
2. Evaluates these indicated needs and their priorities.
3. Initiates projects for which standards-making action is required.
4. Indicates the appropriate time frame within which action should be completed.
5. Identifies the parties of interest, and the procedures to be followed to assure consideration of their views.
6. Selects the appropriate standards-development procedure and assigns the project to the body best able to carry out that procedure, avoiding duplication to the extent practicable.
7. Reviews each standard produced.
8. Assigns each standard an appropriate classification and designation which is a part of a national series.
9. Arranges for distribution of work and coordination among the various organizations involved.
10. Provides for periodic review and maintenance of standards produced.

Even though this is a voluntary standards system, the mechanism for accomplishing these various management functions must involve both the public and private sectors of the society.

The need for standards development can arise within industry, government, labor, consumers, academia, or within the standards development community itself. Such a need may or may not be related to a need for regulation, certification, accreditation, communication, or product interchangeability or interconnection. Regardless of where or for what reasons the need arises, it may be initially addressed by the community in which it arises or it may be taken immediately to the standards-making management or coordination body or both. If, after completion, the consequences of the use of the standard impinge on communities in the society other than those where the need arose, there must be coordination and management provided from outside that community. The number of cases in which a community that consists even of a single corporate body can develop and use standards developed in-house to govern its own internal operations is progressively becoming fewer. Hence, the scope and complexity of the standards management system and the diversity of the areas of societies with which it must interact will progressively enlarge.

The time frame within which the need for a standard must be met by production of a suitable standard will vary from as short as a few weeks to as long as a few years. The voluntary standards-making system must include provisions for the employment of expedited procedures when such are needed.

The keystone of any voluntary standards system is the acceptability of the standards produced. Acceptability implies more than technical soundness and can be attained through due process

a described in Part III of this report under the definition of a consensus standard.

The ideal voluntary standards system must include provisions for categories of voluntary standards, not only with respect to the matters standardized (as methods, definitions, practices, etc.), but also with respect to the breadth of the consensus reached (that is, within a single enterprise, within an industry, within a geographical area, within the nation, within a group of nations). For example, there may be an Eastman Kodak Company standard relating to a photographic product or process; a plywood industry standard for a plywood product or process; a Virginia Highway Department standard for highway marking; an American National Standard for automobile safety belt testing; or an international standard method for determining the concentration of mercury in seawater. Regardless of the size of the population affected by the standard, a consensus of interested and affected parties from that population must be determined to have been achieved if the resulting standard is to have credibility within that population.

The ideal standards management system must create procedures that guarantee such consensus and additional procedures for reviewing actions taken to ascertain that due process was followed. When it has been demonstrated that the procedures were followed properly, then the standard must be assigned an appropriate designation in its proper category and disseminated for use. The standard management systems must put in place an authoritative body to administer the procedures and rule on the acceptance of the standards generated under them.

COORDINATION IN THE IDEAL SYSTEM

A major part of the ideal voluntary standards system is its coordination force - a private or quasi-public body with national recognition by government, industry, academia, labor, and other elements of society. This coordination body will provide a mechanism to:

1. Appraise the existing standards, their scope, and usefulness.
2. Determine the capabilities of standards-development organizations.
3. Keep abreast of the standards development work in progress and the timetables for its completion.
4. Determine the need for standards not already under development.
5. Establish priorities for new standards, taking into account the development procedures, capabilities, and resources of the existing standards-making bodies.
6. Identify and eliminate overlap and duplication of standards and standards development work to the extent practicable.

This part of the ideal system can work only if the many standards-writing organizations are willing to give the coordinating body the authority to make basic coordination decisions.

Such decisions would include:

1. Determination of the most competent organization to do a particular standards development task.
2. Resolution of disputes on the scope of work to be carried out by the various standards-writing organizations.

IDENTIFICATION OF NATIONAL STANDARDS

The ideal voluntary standards system will include a plan for classifying and identifying standards approved as national voluntary standards. This identification will appear on each standard and, if necessary, in addition to the identification which the organization producing the standard has assigned to it. This will permit the publication of a single catalog of all approved national voluntary standards.

ACCREDITATION OF STANDARDS-MAKING ORGANIZATIONS

The ideal voluntary standards system for the United States is one that gives special recognition to those standards-making organizations that produce standards that represent a consensus of all interested parties. To provide this recognition, the ideal system will have an accreditation board for the examination of standards-making procedures of various organizations and the accreditation of those that are able to produce national consensus standards. As long as the procedures of an organization have been accredited, all its standards would be recognized as official national standards. The accreditation board would re-examine the procedure regularly and reaffirm or withdraw the accreditation as necessary. Standards produced by unaccredited organizations would not be accepted as official national standards until the completion of further procedural steps specified by the accreditation board. The additional steps might not be the same for all situations.

CENTRAL ORGANIZATION

Most of the work of the ideal voluntary standards system will be carried out by the several hundred standards-making organizations that comprise the system, but there will have to be at least a small central organizational structure to:

- Operate the coordinating body.
- Operate the accreditation board. Classify and identify the standards approved.
- Publish the rules governing the operation of the system.

The central organization may be able to assume other public relations or public service functions, but its major role in the ideal U.S. voluntary standards system is that just described.

APPENDIXES

APPENDIX I. WORKSHOP PROGRAM

Wednesday, October 11, 1995

9:00am - 11:30am	*Opening Presentations*
Welcome	Geoffrey Frohnsdorff Building & Fire Research Laboratory, NIST
Future Standards for Concrete	George F. Leyh Executive Vice President American Concrete Institute
Future of Standards	James A. Thomas President American Society for Testing and Materials
Standards Media and Methods	Richard N. Wright Director Building and Fire Research Laboratory, NIST
Keynote Presentation	
Cement and Concrete Standards for the Future	Bryant Mather Director Structures Laboratory U.S.Army Engineer Waterways Experiment Station

Wednesday October 11, 1995

11:30am - 12:30pm — *Working Groups*

WG1: **Concrete Materials Standards**
Chair: David Fowler
Recorder: Dale Bentz

WG2: **Concrete Materials Standards**
Chair: Robert Helinski
Recorder: Paul Stutzman

WG3: **Concrete Standards**
Chair: Douglas Hooton
Recorder: Clarissa Ferraris

WG4: **Concrete Standards**
Chair: Oscar Tavares
Recorder: Ken Snyder

WG5: **Design and Construction Standards**
Chair: Gene Corley
Recorder: S. Shyam-Sunder

WG6: **Design and Construction Standards**
Chair: Richard N. White
Recorder: Jim Pielert

1:30pm - 5:00pm — *Working Groups (Continued)*

Thursday October 12, 1995

9:00am - 12:30pm — *Working Groups (Continued)*

1:30pm - 3:30pm — *Plenary Session: Working Group Reports*

Closing Discussion and Recommendations

APPENDIX II. SPONSORING ORGANIZATIONS, STEERING AND ORGANIZING COMMITTEES

Sponsoring Organizations

- American Concrete Institute (ACI)
- American Society for Testing and Materials (ASTM)
- Canadian Standards Association (CSA)
- Organismo Nacional de Normalizacion y Certificacion de la Construccion y Edificacion (ONNCCEE), Mexico
- National Institute of Standards and Technology (NIST)

Steering Committee

- Paul Breeze, ACI
- Oscar Tavares, ASTM Committee C01
- James Pierce, ASTM Committee C09
- Geoffrey Frohnsdorff, NIST (Chairman)

Organizing Committee

- Nicholas J. Carino, NIST
- Kenneth Chong, National Science Foundation
- James R. Clifton, NIST
- Geoffrey Frohnsdorff, NIST (Chairman)
- Richard Gaynor, National Ready-Mixed Concrete Association
- Joseph F. Lamond, Consultant
- Tony Liu, U.S. Army Corps of Engineers
- Nancy Wilkin, NIST (Secretary)

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APPENDIX V. ISSUES PROPOSED FOR DISCUSSION AT THE WORKSHOP

Prior to the workshop, interested parties were asked to submit up to four topics for possible discussion at the workshop. The suggestions received were much appreciated. They are listed herein to supplement the recommendations from the workshop (Chapter 3) because they draw attention to many important issues that should be considered by standards committees when revising existing standards or developing new standards. While many of them were discussed at the workshop, time did not allow for all to be discussed. The classification of the topics is somewhat coarse as the topics covered such a wide spectrum. While some editing of the subjects submitted has been performed to present them in similarly concise formats, we believe that the essence of each submission has been retained.

V.1 General Issues

V.1.1 Standards Development Process

- More rapid procedures for standards modification.
- How can we achieve standards that are reflective of current technology?
- How to incorporate research results into standards?
- How do we deal with the time issue (making things happen within a reasonable time)?
- Transfer of information from R&D/academia to industry.
- Provide assistance for rationalizing deletion of obsolete standards requirements

V.1.2 Standards Organizations and Harmonization

- Re-examine the ASTM/ACI agreement for possible modifications to facilitate standards development.
- How do we compare with European standards?
- How can we achieve certification of mutual recognition?
- Better liaison between ASTM-ACI-BOCA.
- Promote acceptance by ISO of ASTM/ACI standards.
- Clarify the roles of ASTM and ACI, especially for "others."
- How do you make sure the same people are involved in both domestic and international standards?
- How do we deal with international issues (e.g. environmental issues in both developed and undeveloped countries)?
- Is harmonization a reality or a perception in our industry?
- How do we continue to grow without taking less for the benefit of harmonization with other countries?

- How do we initiate an investigation of the implications of standards harmonization between the U.S. and other countries?
- Areas where technological, scientific or environmental and social factors interact and cause us to re-evaluate our standards: A movement towards an industrial, environmental and political partnering would address this issue. An example would be the development of specifications that allow cement companies to increase alkalies, thereby mitigating the kiln dust issues.
- Should standards reflect "harmonization" ?

V.1.3 Conformance Assessment

- Development of more effective rapid test methods and procedures.
- Rapid testing for performance standards.
- QA/QC

V.1.4 Durability

- Durability standards.
- Focus on long-term performance.
- Improvement in durability and serviceability.
- Standards which encourage the use of waste materials.

V.1.5 Performance vs. Prescriptive Standards

- Performance standards vs. design or prescriptive standards.
- Removing the risk from performance specs.
- Do performance specifications offer adequate protection?
- Less empiricism - more rational models.
- Real world status of performance specifications for cement and concrete.
- Develop more performance standards.
- Establish rational bases for use of performance and prescriptive standards.
- Should future standards reflect a mark of quality or a minimum standard?

V.1.6 Integrating Standards

- Removing barriers for use of new standards.
- Improved cooperation between producer and contractor.
- Strengthening ties between cement and concrete standards.

V.1.7 Technology Transfer/Information Technology

- Consider a program for joint ASTM/ACI publications.
- Incorporate computer interfacing for measurements of small quantities such as volume change
- Establish a record-keeping system to document the bases for limits established in standards.
- Develop an industry index of standards and reports.
- Enhance the communication among involved organizations to provide adequate information and avoid duplication of effort.
- How can we disseminate information more effectively?
- A concrete supplier of the future should receive statistical information about their incoming ingredients. The information would relate to the performance of the product they are producing.
- Preserve records of the development of a standard. This is important if an existing standard is to be used as the basis for a new standard.

V.2 Issues Relating to Concrete Materials

- Improved aggregate test methods to predict field performance.
- Aggregate quality concerns/standards for use in high-performance concrete.
- Performance standards for cements.
- Improved blended cement standards.
- Composite cements/blended cements performance standards.
- Can the "carbonate issue" be resolved without going backwards?
- The workshop should address new generation cementitious materials.
- Raising the lower limit of cement strength at certain ages.
- Sulfate content (clinker $S0_3$ vs. total).
- Environmental issues related to cement - for instance, health hazards.
- More restrictive materials standards.

V.3 Issues Relating to Concrete Materials and to Concrete

- Performance-based cement and concrete standards.
- Standards for lithium admixtures used to prevent alkali-aggregate expansive reactions.
- Development of methods for identifying deterioration mechanisms.
- Durability-based, rather than strength-based, tests.
- Few cement standards actually predict how cement will perform in concrete.
- Delayed ettringite formation (DEF) - I am told that C150 and C595 do not guarantee the performance of concrete as it relates to DEF. Some organizations are recommending an SO_3 maximum of 1% in clinker, apparently as a safeguard against

DEF. We need performance tests to cover DEF.

- Strive for test methods and standards that relate to one another. An example would be the inability to relate concrete and cement specifications. A concrete supplier uses the information generated under ASTM C 150 to make judgments pertaining to concrete performance.
- A better understanding of local conditions that would impact a national specification of a writer's decision would be helpful. Probably we could end up with a book that is a synopsis of area concerns, general recommendations on how to accommodate these concerns, along with a site carrying out related research.
- Issues related to precision and accuracy, bias, calibration and like considerations. The precision of a method and associated specification limits need to be developed with the limits being properly achievable with the given calibration of the test method. Without proper thought, we develop unachievable specifications; therefore, the importance of the calibration needs to drive the method and specification, and just not to be an irritable requirement of the standard development.

V.4 Issues Relating to Concrete

- The ASTM C1201 coulomb test should not be used for specification of concrete.
- Establish more freshly mixed concrete tests for acceptance/rejection.
- Develop a test method for in-situ assessment of alkali-silica reaction potential in concrete.
- There is a need for measures of concrete quality other than 28-day strength, particularly when durability is an issue.
- Change the industry over to new rebar deformations per research at the University of Kansas.
- Promote R&D to a) make durable concrete without using entrained air, and b) make self-sealing (curing) concrete.
- Adopt a fail safe position to provide proper air entrainment unless someone requests non-air entraining concrete.
- Accelerated durability testing of concrete.
- QA and QC tests for high-performance concrete.
- Characteristics of concrete mixture design.
- Practical value of testing the resistance to freezing/thawing cycles by ASTM C666.
- The need for developing standard test methods for tensile creep and modulus of elasticity.
- Address the issue of clarifying the distinctions between "curing" and "treatments applied to new concrete."

V.5 Issues Relating to Concrete and Design and Construction

- Graduated acceptance limits based on degree of noncompliance.
- Graduated acceptance limits based on environmental severity.
- Graduated acceptance limits based on desired service life.
- Definitions and standards for high-performance concrete.
- Consideration of thermal compatibility of concrete in structural design.
- Tests to quantify fatigue damage on early "open to traffic" projects.
- Establish or refine non-destructive test methods which can be evaluated in an objective and relatively simple manner by the average practitioner.
- Develop a guide to standardize NDT evaluations; e.g., number of cores needed, locations of cores, and evaluation of strength values obtained.
- How can we achieve standards that are reflective of performance of concrete systems?

V.6 Issues Relating to Design and Construction

- Move towards a common international design code.
- Taking full advantage of attributes of high-strength/high-performance concrete.
- Code provisions for non-metallic reinforcement/prestressing.
- Codes/standards for hybrid and composite construction; effective ways to deal with concrete and steel shapes used creatively in a structure.
- Composite concrete performance standards.
- The need for developing a reliable drying shrinkage test method (or methods).
- How do we compare with the steel industry?

APPENDIX VI: A VISION OF THE CEMENT AND CONCRETE STANDARDS OF THE FUTURE

As stated in the report, it is expected that the invited talks and the recommendations from the working groups will stimulate discussion about cement and concrete standards of the future, thereby contributing to the vitality and quality of the standards development process for these materials. To contribute to the discussion, the editors of this report have drawn on what they heard at the workshop to try to synthesize a plausible vision of what cement and concrete standards might be like, and how they might be developed, at some time in the not-too-distant future – perhaps by 2010 -- if most, or all, of the workshop recommendations were acted upon:

Development of the cement and concrete standards of the future will be facilitated by the use of computer aids equivalent to shells used in the development of expert systems. The standards themselves will commonly be expressed in the form of executable objects (i.e., computer programs) rather than as printed texts. This will be significant because the mandatory portions of standards will be able to be supported by large amounts of explanatory material which can be referred to in whatever depth is desired by the user. It will also be significant because each standard will be able to be interfaced with other executable standards and software of many types; for example, as test results are obtained using a standard test method, the data could be immediately entered into a database which included data from other tests on the same material; further, the data could be immediately processed with software that, for example, analyzed the results for consistency with previous results and suggested possible causes for any apparent anomalies.

Designers of structures will be aided by standards for service life design, and by standards (and building codes) that give guidance on the levels of performance to be expected from different designs after catastrophic events. Standards will also be available for hybrid concrete construction, and for active and passive vibration control of concrete structures. To provide reliable information on new and improved concretes, standards will be available for high-performance concretes with higher strengths and longer service lives than the typical concretes of today, and there will be performance criteria and design/construction standards for fiber-reinforced concrete. Performance-based standards will be commonplace and will co-exist with prescriptive standards; they will facilitate evaluation of new materials and materials to be used under unusual conditions. The performance-based standards will depend on a more complete range of standard performance test methods than is available at present and the need for long-term testing will be reduced; this will be because of ability to predict performance over time from the characteristics and proportions of the materials,

the conditions of their mixing and processing, and the expected service environment for the product. Examples of new standard performance tests that will be available are for determination of the rates of transport of fluids in concrete and other cement-based materials, for toughness, and for thermal compatibility of the constituents, and the performance predictions will use improved methods of characterization of concrete and concrete materials. There will also be standards for computerization of data obtained from standard, and other tests.

With the continuing need to extend the lives of, rather than replacing, older structures, there will be new and improved standards for condition assessment and for repair and rehabilitation. Among standardized techniques for use in inspection and condition assessment will be techniques using radar and stress wave propagation. Performance standards for repair materials will include standards for compatibility of repair materials with the materials to be repaired and with other repair materials with which they may be used.

Quality control and quality assurance will become tighter. Standards for certification of technical personnel in laboratories, in concrete plants, and in construction organizations will be available and frequently applied. There will be standard methods for performing quality audits on hardened concrete and concrete structures. As part of a rational and realistic acceptance procedure for concrete, graduated acceptance limits will often be defined in purchasing contracts.

The body of standards available to the concrete community, and to the construction community as a whole, will include standards for life-cycle cost analysis and life cycle ("cradle-to-grave") assessment of environmental impacts.

With the growth of international trade resulting from international trade agreements, there will be increased use of international standards, including standards for cement and concrete. The U.S. should therefore develop cement and concrete standards suitable for use as international standards and be an active participant in international standards organizations. Standards will often be harmonized internationally, but regional standards will still exist, and some new ones, e.g., for NAFTA, could be developed. Standards will all be completely metric and use SI units.

To reduce the time of standards development (from research to standard), standards facilitators will be provided. Standards facilitators will be used increasingly to speed the work of standards-writing committees as the efforts of the traditional volunteers decrease; use of electronic communications will also facilitate committee work and will serve to bring in new participants who are attracted by the opportunity to strengthen the scientific basis for standards but who cannot spare time to attend the traditional standards committee meetings.